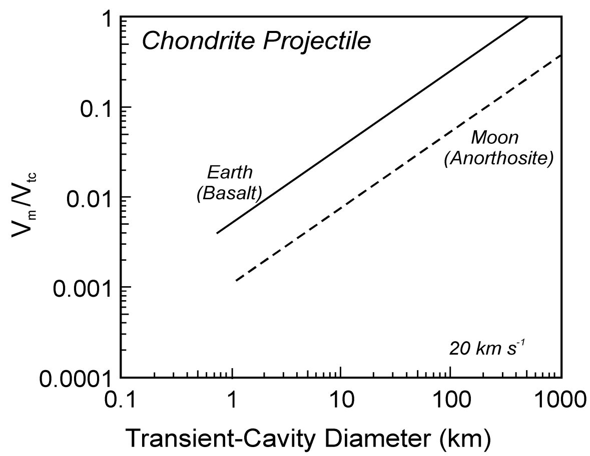
LARGE-SCALE IMPACT CRATERING AND EARLY EARTH EVOLUTION. R. A. F. Grieve[1] and M. J. Cintala[2], [1]Geological Survey of Canada, Ottawa, Ontario, Canada, [2]NASA Johnson Space Center, Houston TX, USA.

The surface of the Moon attests to the importance of large-scale impact in its early crustal evolution. In fact, previous models of the effects of a massive bombardment on terrestrial crustal evolution have relied on analogies with the Moon, with allowances for the presence of water and a thinner lithosphere [1–3]. It is now apparent that strict lunar-terrestrial analogies are incorrect because of the "differential scaling" of crater dimensions and melt volumes with event size and planetary gravity [4,5].

Impact melt volumes and transient cavity dimensions for specific impacts were modeled according to previous procedures [4,5]. In the terrestrial case, the melt volume (V_m) exceeds that of the transient cavity (V_{tc}) at diameters ≥400 km (see Fig. 1). This condition is reached on the Moon only with transient cavity diameters ≥3000 km, equivalent to whole Moon melting [6]. The melt volumes in these large impact events are minimum estimates, since, at these sizes, the higher temperature of the target rocks at depth will increase melt production.

Using the modification-scaling relation of Croft [7], a transient cavity diameter of ~400 km in the terrestrial environment corresponds to an expected final impact "basin" diameter of ~900 km. Such a "basin" would be comparable in dimensions to the lunar basin Orientale. This 900-km "basin" on the early Earth, however, would not have had the appearance of Orientale. It would have been essentially a melt pool, and, morphologically, would have had more in common with the palimpsests structures on Callisto and Ganymede [8]. With the terrestrial equivalents to the large multiring basins of the Moon being manifested as muted palimpsest-like structures filled with impact melt, it is unlikely they played a role in establishing the freeboard on the early Earth [2,9].

The composition of the massive impact melt sheets (>10^7 km^3) produced in "basin-forming" events on the early Earth would have most likely ranged from basaltic to more mafic for the largest impacts, where the melt volume would have reached well into the mantle. Any contribution from adiabatic melting or shock heating of the asthenosphere would have had similar mafic compositions. The depth of the melt sheets is unknown but would have been in the multikilometer range. Bodies of basaltic melt ≥300 m thick differentiate in the terrestrial environment, with the degree of differentiation being a function of the thickness of the body [10]. We therefore expect that these thick, closed-system melt pools would have differentiated into an ultramafic-mafic base and felsic top. If only 10% of the impact melt produced in a single event creating a 400-km diameter transient cavity evolved into felsic differentiates, they would be comparable in volume to the Columbia River basalts. It has been estimated that at least 200 impact events of this size or larger occurred on the early Earth during a period of heavy bombardment. We speculate that these massive differentiated melt sheets may have had a role in the formation of the initial felsic component of the Earth's crust.



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